

CIE TEST CASES — BEWERTUNG DER GENAUIGKEIT VON SOFTWAREBASIERTER LICHTBERECHNUNG

Dipl.-Ing. Carolin Liedtke
Technische Universität Berlin, FG Lichttechnik

Kolloquium über optische und lichttechnische Fragen
TU Berlin, E 020
05.02.2014, 17:15 Uhr

*Ergebnisse der CIE Test Cases - Stand Oktober 2013,
Für Dialux 4.11, Relux Pro 2013.1.3.0*

CIE Test Cases

- Hintergrund
- Struktur & Vorgehensweise
- Szenarien mit experimentellen Referenzdaten
- Szenarien mit analytischen Referenzdaten
- Zusammenfassung

Ausblick

Wie akkurat sind die berechneten lichttechnischen Größen?

→ Entwicklung von Test-Szenarien

1999 Fontoynt et.al.

Erster standardisierter Test (IEA –SHC Task 21/ECBCS Annex 29)

Ergebnis: großer Einfluss durch die Qualität der Eingabedaten

2003 Maamari & Fontoynt

Entwicklung eines Test-Szenarien-Sets

Beispielhafter Vergleich von Lightscape & Relux Professional 2004

Basis für die Entwicklung der CIE Test Cases

CIE "Test Cases to assess the Accuracy of Lighting Computer Programs", Technical Report, TC. 3.33 April 2005

CIE 171:2006: "Test Cases to assess the Accuracy of Lighting Computer Programs", ISBN 9783901906473

„Anleitung für Entwickler und Nutzer [...] zur Beurteilung der Genauigkeit lichttechnischer Computerprogramme und zur Ermittlung eventueller Schwächen“

Vorschlag eines Berechnungsverfahrens zur getrennten Prüfung einzelner Aspekte der Lichtausbreitung

Referenzdaten auf experimenteller und analytischer Basis

Beschreibung des Vorgehens und der Auswertung

- Innenbeleuchtung
- Künstliche Beleuchtung und Tageslicht
- Direkte und Indirekte Beleuchtung
- Berechnungen mit Radiosity und Raytracing

Unzureichend für

- Gerichtetes Licht
- Berücksichtigung spektral abhängiger Größen

CIE Test Cases - Übersicht

4.1 CFL, grey	5.2 Point light sources	5.6 Light reflection over diffuse surfaces	5.9 SC (roof unglazed opening)	Sun patches
4.2 Opal, grey	5.3 Area light sources		5.10 SC (roof glazed opening)	Specular reflections
4.3 Semi-specular, grey	5.4 Flux conservation	5.7 Diffuse reflection with internal obstructions	5.11 SC + ERC (façade glazed opening)	Transmission through ideal glazing
4.4 CFL, black				Reflection on bi-directional glazing
4.5 Opal, black	5.5 Directional transmittance of clear glass	5.8 Internal reflected component calculation for diffuse surfaces	5.12 / 5.13 SC + ERC (unglazed façade opening) with continuous horizontal/vertical mask	Spectral calculation
4.6 Semi-specular, black				External illuminance variation
				Variation of external illuminance (date)
				Leaks into enclosed areas

Artificial lighting scenario Daylighting scenario

Experimental test case Analytical test case Proposed test case

Experimental Test Cases

- 4.1 CFL, grey
- 4.2 Opal, grey
- 4.3 Semi-specular, grey
- 4.4 CFL, black
- 4.5 Opal, black
- 4.6 Semi-specular, black

Analytical Test Cases

- 5.2 Point Light Sources
- 5.3 Area Light Sources
- 5.4 Flux Conservation
- 5.8 Internal reflected component calculation for diffuse surfaces

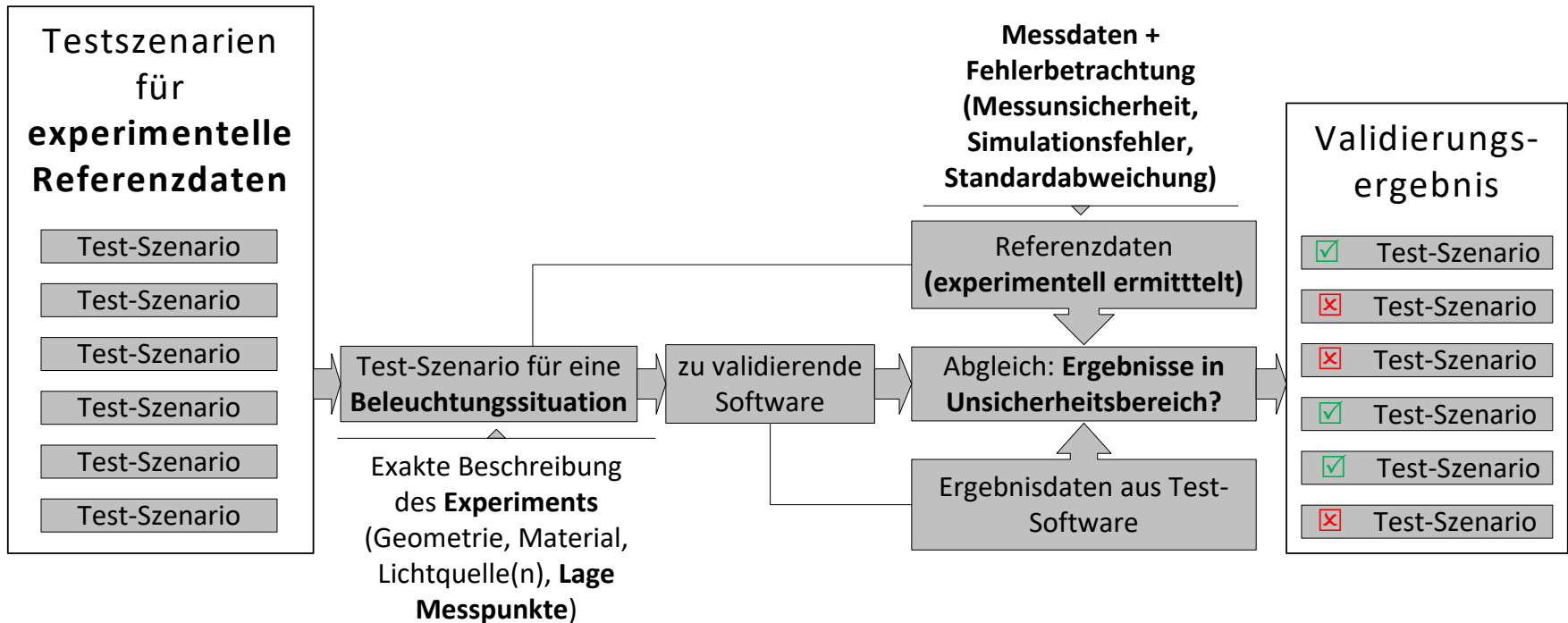
Experimental Test Cases

- 4.1 CFL, grey
- 4.2 Opal, grey
- 4.3 Semi-specular, grey
- 4.4 CFL, black
- 4.5 Opal, black
- 4.6 Semi-specular, black

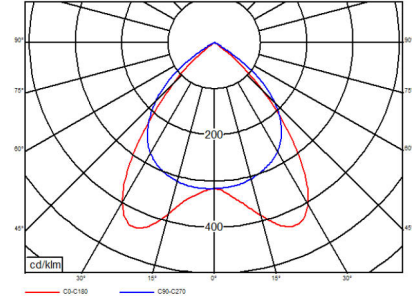
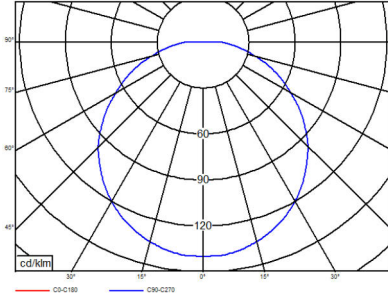
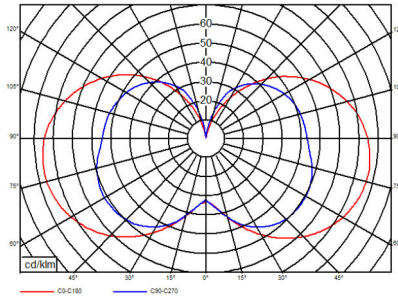
Analytical Test Cases

- 5.2 Point Light Sources
- 5.3 Area Light Sources
- 5.4 Flux Conservation
- 5.8 Internal reflected component calculation for diffuse surfaces

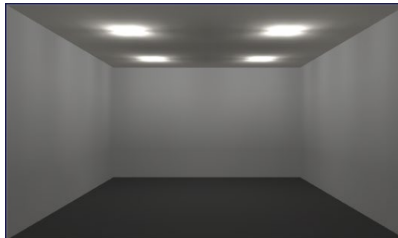
Experimentelle Referenzdaten



Experimental Test Cases 4.1-4.6



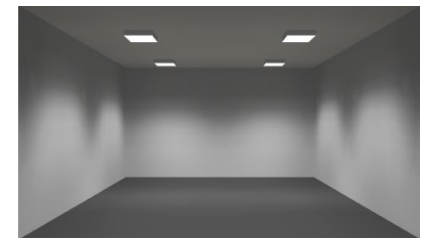
4.1



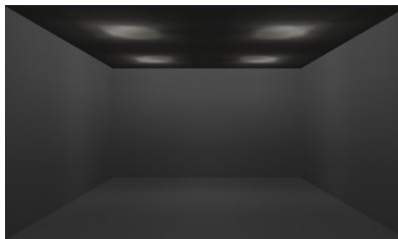
4.2



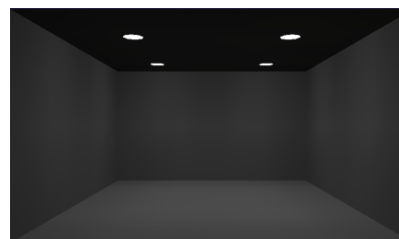
4.3



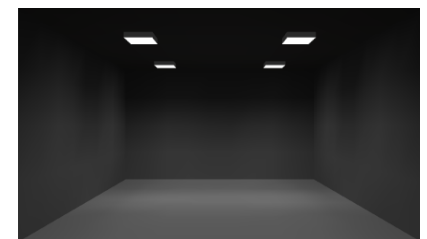
4.4



4.5



4.6



Experimental Test Cases 4.1-4.6



	Aim	To assess simulation against measurements in real scenes
	Measured parameter	Illuminance values in a 7x7 grid
	Result	Point illuminance values Average illuminance
Setting	Room geometry	6,78 m x 6,72 m x 3,24 m
	Measurement grid	7 x 7 at 0,8 m height
	Luminaire position	L1 (1,695 m; 5,04 m; 3,14 m) L2 (1,695 m; 1,68 m; 3,14 m) L3 (5,085 m; 5,04 m; 3,14 m) L4 (5,085 m; 1,68 m; 3,14 m) (Exception: 4.2/4.5 height 3,2 m)
	Luminous flux input	L1 (2182 lm) L2 (2196 lm) L3 (2203 lm) L4 (2182 lm) (4.1, 4.4) L1 (1850 lm) L2 (1830 lm) L3 (1870 lm) L4 (2110 lm) (4.2, 4.5) L1 (4088 lm) L2 (4175 lm) L3 (4135 lm) L4 (4114 lm) (4.3, 4.6)
Varied parameter	LID	CFL LID, Opal LID, Semi-specular LID (Annex A)
	Reflectance	Ceiling (70%), Wall (41%), Floor (6%) (4.1) Ceiling (70%), Wall (52%), Floor (6%) 4.2, 4.3 Ceiling (3%), Wall (4%), Floor (6%) (4.4, 4.5, 4.6)

Experimental Test Cases 4.1-4.6

Measurement Errors	Effect on average illuminance %	Effect on direct point illuminance %
Sensors		
Cosine correction	0.5	2
Colour correction	1	1
Calibration	2	3
Repeatability of position	0	3
Leveling	0	2
Photometry factors affecting measurement		
Lumen output – temp	2	2
Lumen output – power	1	1
Room factors		
Dimensions and irregular features	0.5	0.5
Luminaire positions	0	2
Measurement positions	0	2
Surface reflectance	2	2
Total measurement error	3.8	6.7

Table 2: Measurement Error Estimates [CIE 171:2006]

Experimental Test Cases 4.1-4.6

Simulation Errors	Effect on average illuminance %	Effect on direct point illuminance %
Photometry factors affecting simulations		
Output distribution	0	5
Lumen output	5	5
Output photometry v. real situation		
Intervals in TM 14 format	0	4
Total Expectation of error	6.3	10.5

Table 3: Total Expectation of Errors [CIE 171:2006]

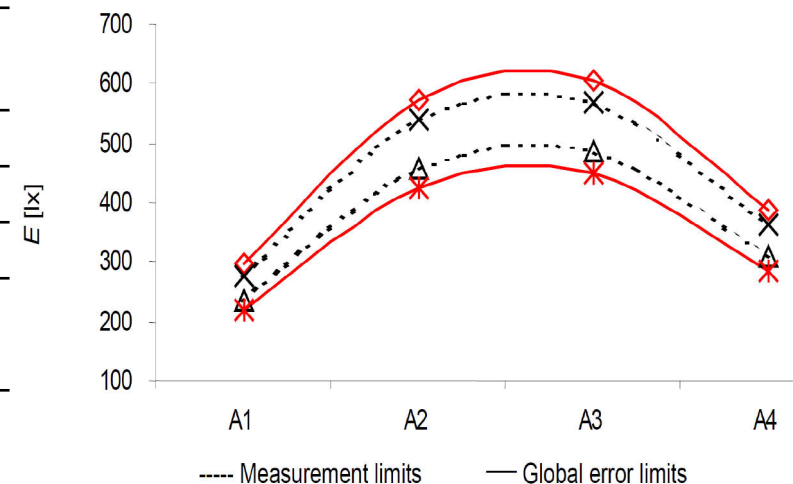
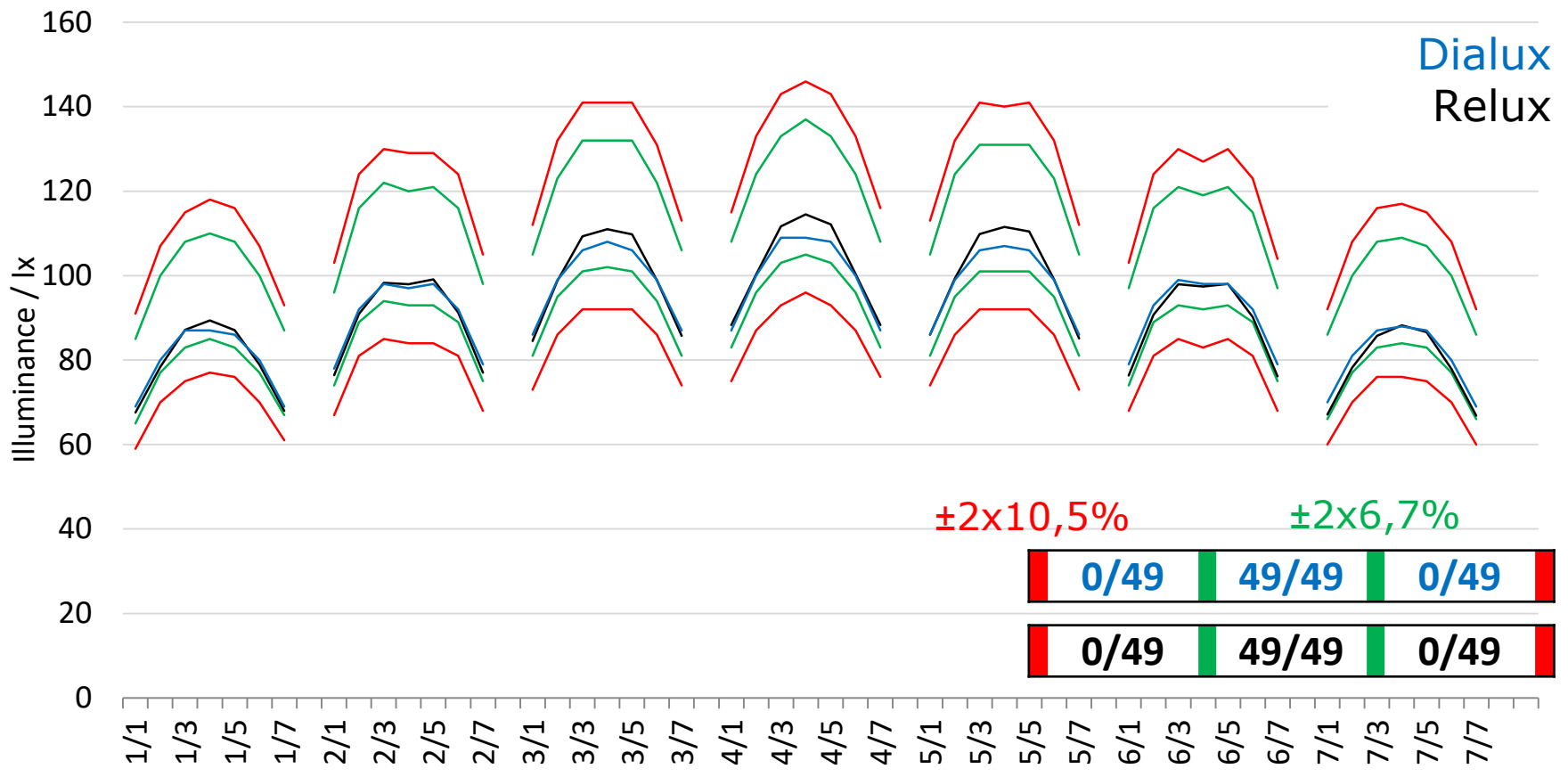


Figure 1: Recommended graphical presentation of experimental measurements [CIE 171:2006]

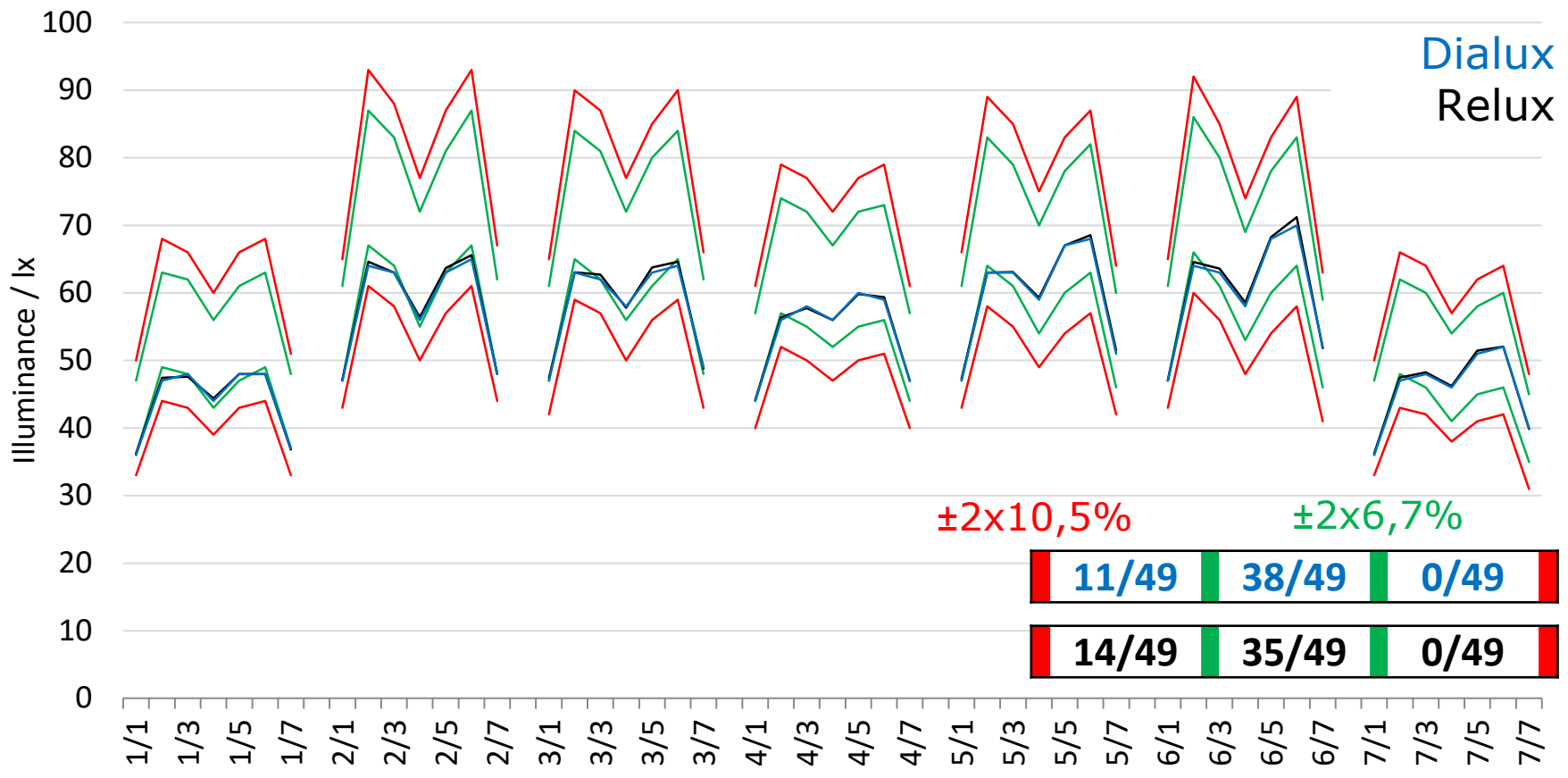
Experimental Test Cases 4.1-4.6

4.1 CFL luminaires – Grey walls



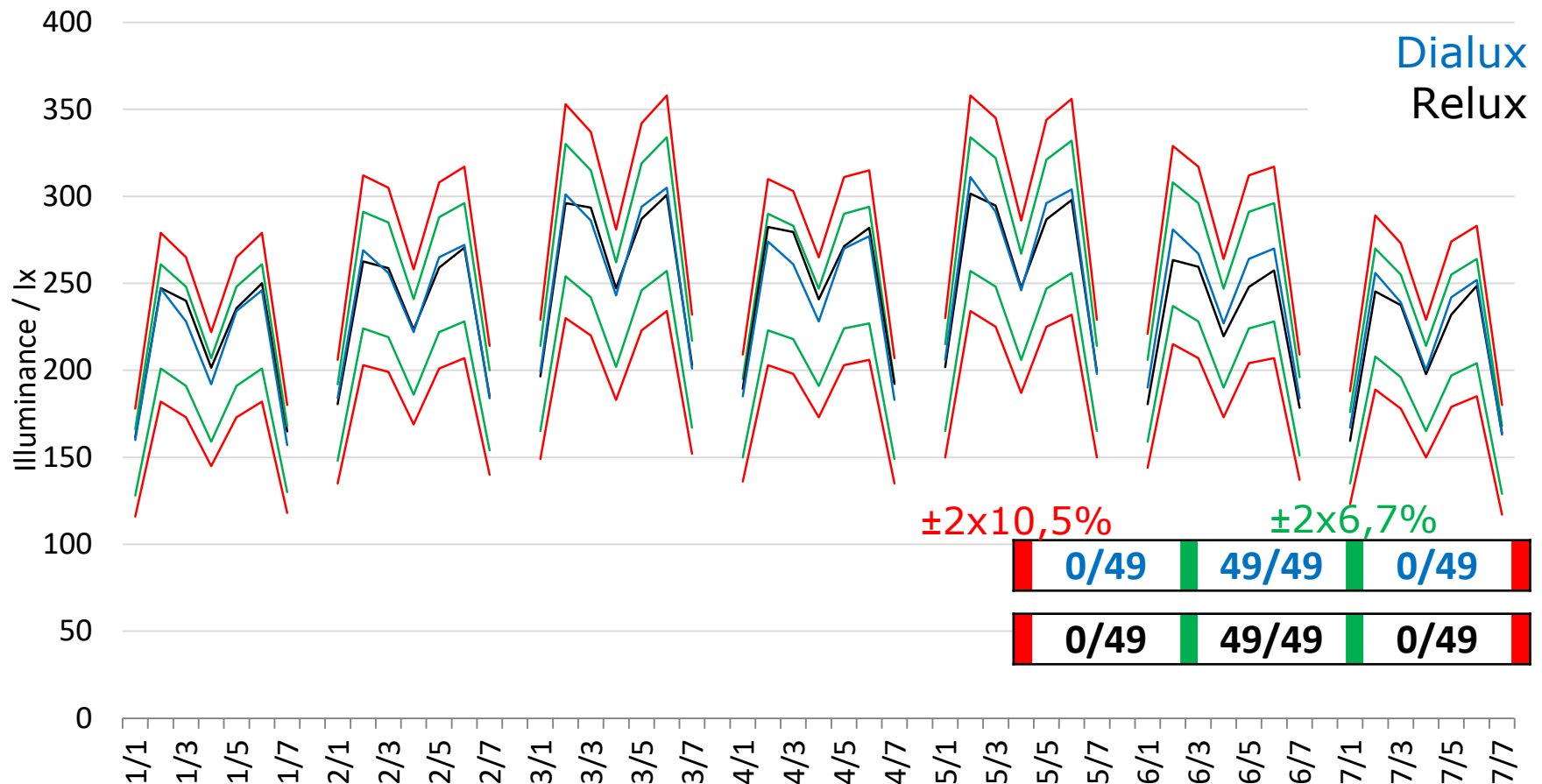
Experimental Test Cases 4.1-4.6

4.2 Opal luminaires – Grey walls



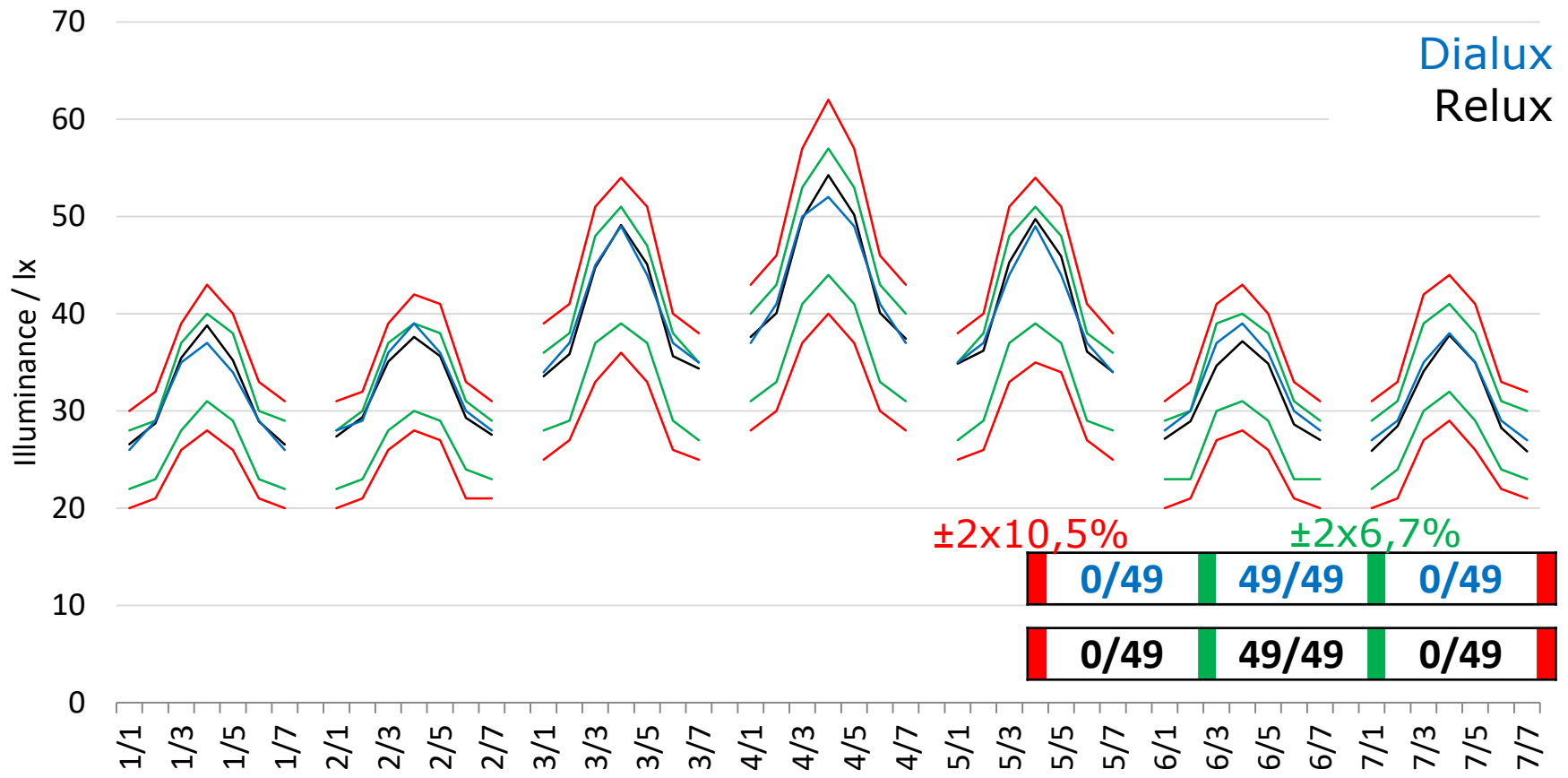
Experimental Test Cases 4.1-4.6

4.3 Semi-specular luminaires – Grey walls



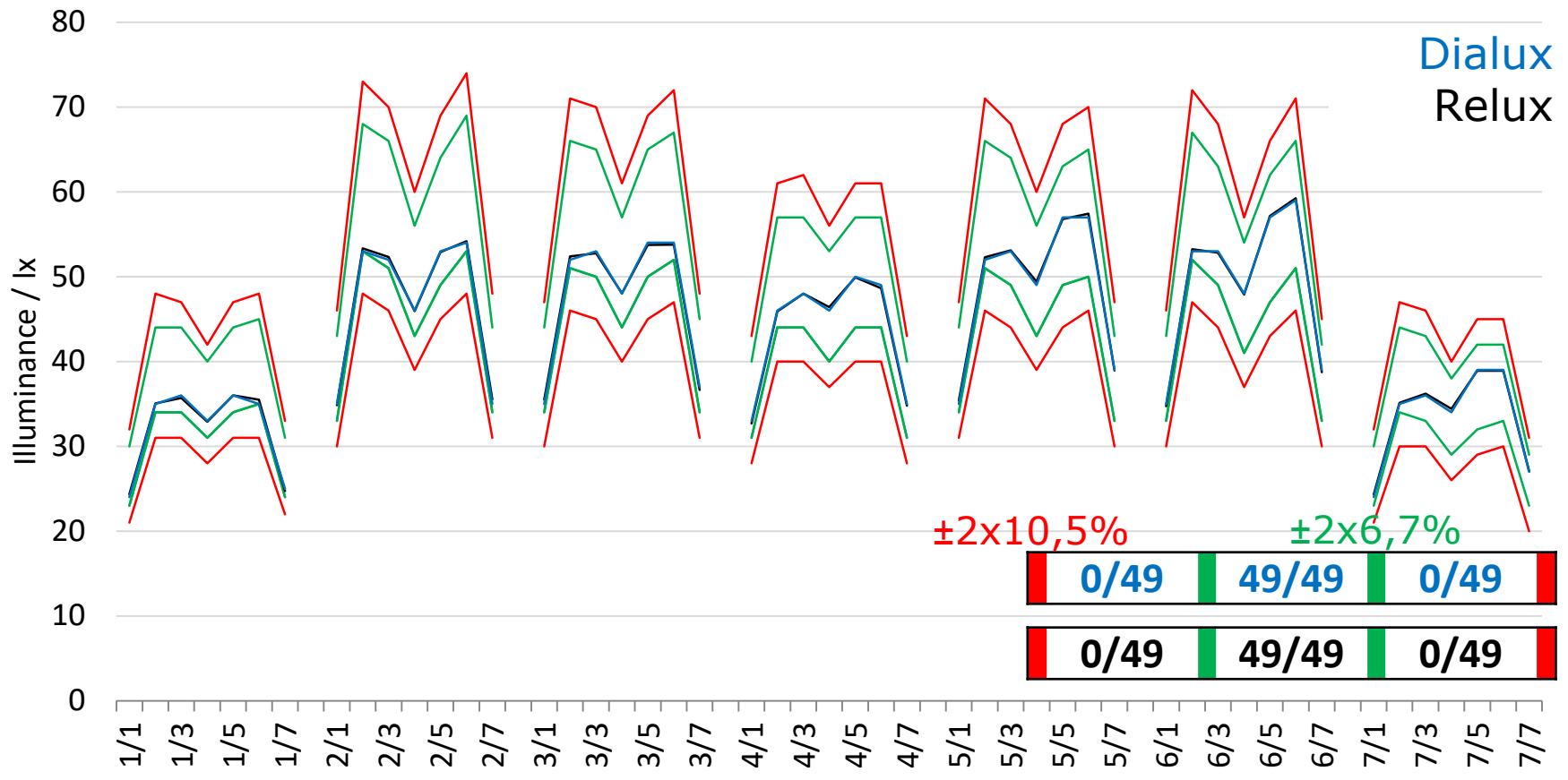
Experimental Test Cases 4.1-4.6

4.4 CFL luminaires – Black walls



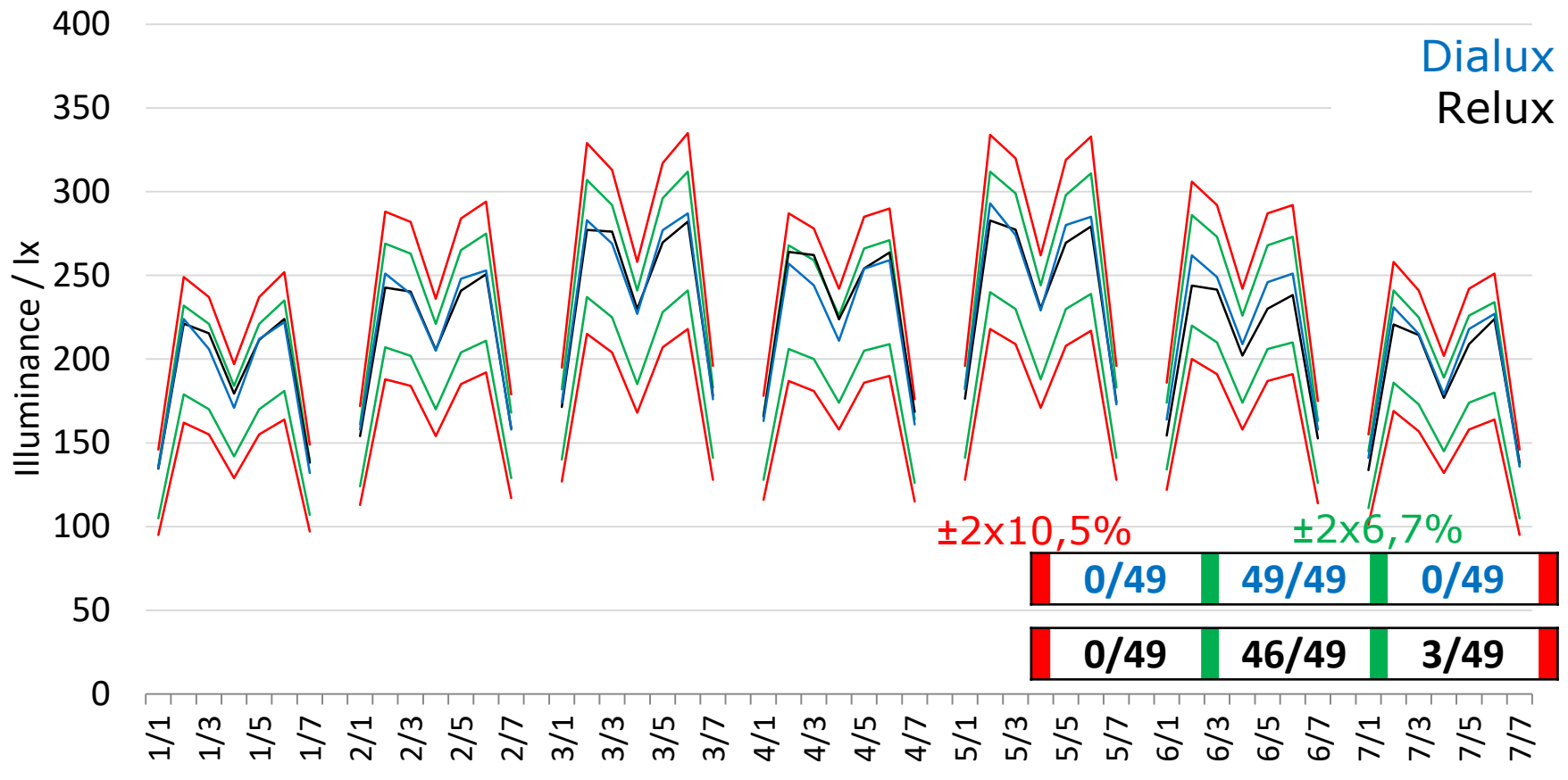
Experimental Test Cases 4.1-4.6

4.5 Opal luminaires – Black walls



Experimental Test Cases 4.1-4.6

4.6 Semi-specular luminaires – Black walls



Experimental Test Cases 4.1-4.6



	4.1 in lx	4.2 in lx	4.3 in lx	4.4 in lx	4.5 in lx	4.6 in lx
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Upper limit (Rf.)	112,0	67,5	254,2	37,5	51,1	228,5
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Dialux
(Simulated Mean
Room Illuminance)

	91	54,0	238	36	43	217
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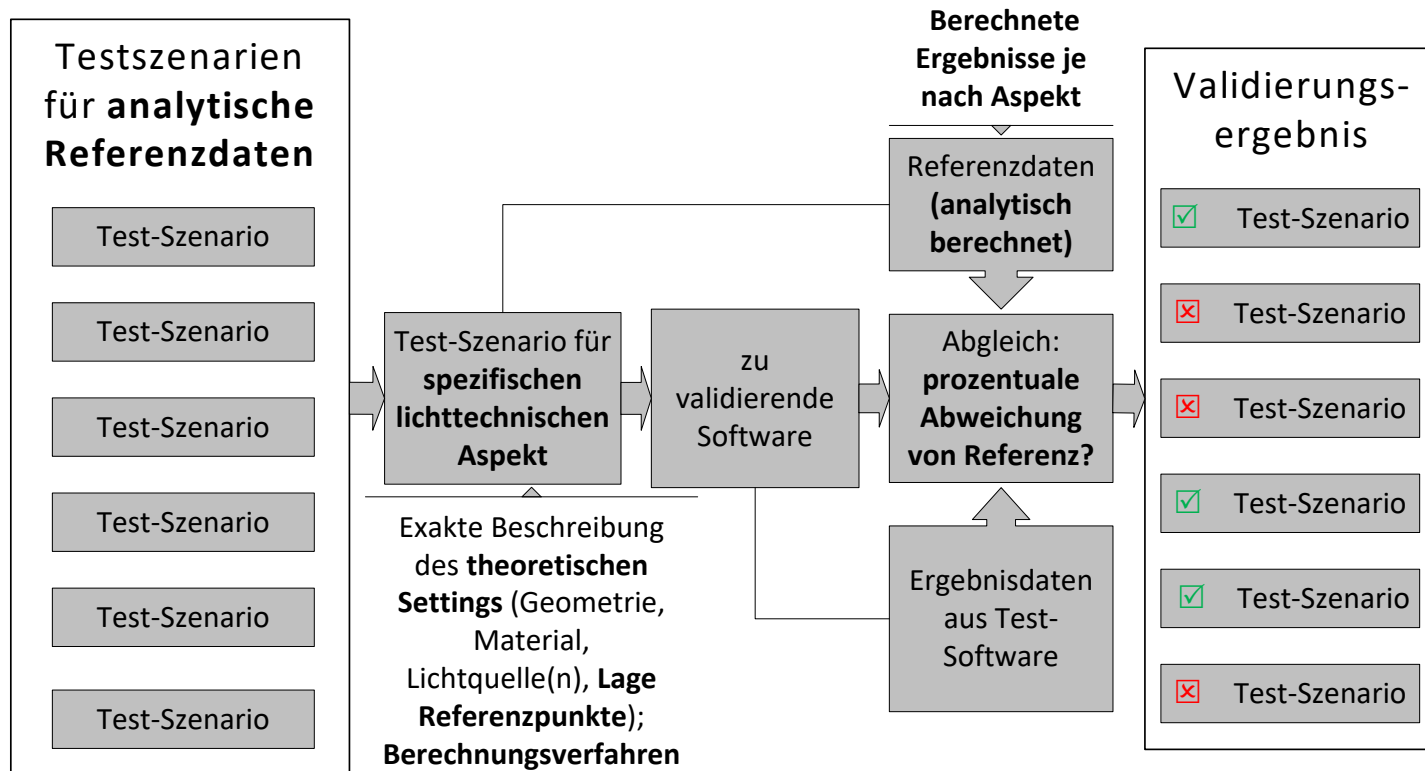
Relux
(Simulated Mean
Room Illuminance)

	91	54,5	237	35,6	43,2	216
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Lower limit (Rf.)	88,0	53,1	199,8	29,5	40,1	179,5
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measurement +/- 2x6,3%

Analytische Referenzdaten



Experimental Test Cases

- 4.1 CFL, grey
- 4.2 Opal, grey
- 4.3 Semi-specular, grey
- 4.4 CFL, black
- 4.5 Opal, black
- 4.6 Semi-specular, black

Analytical Test Cases

- 5.2 Point Light Sources
- 5.3 Area Light Sources
- 5.4 Flux Conservation
- 5.8 Internal reflected component calculation for diffuse surfaces

Analytical Test Cases 5.2/5.3

Aim		To assess the capability of software to calculate the direct illuminance under a <u>point light source</u> an <u>area light source</u> described by a photometric distribution file	
Measured parameter		Direct point illuminance at 10 positions (h)	Direct point illuminance at 14 positions (h / v)
Result		Relative error	
Setting	Room geometry	4,0 m x 4,0 m x 3,0 m	
	Reflectance	Ceiling, Wall, Floor $\rho = 0 \%$	
	Luminaire position	2,0 m; 2,0 m; 3,0 m	
	Luminaire size	1 x 1 mm	1000 x 1000 mm
Varied parameter	LID	Lambertian LID (3142 lm, $I_0 = 1000$ cd)	
		CIE general sky type 9 (3459 lm, $I_0 = 1000$ cd)	

Analytical Test Cases 5.2/5.3

5.2

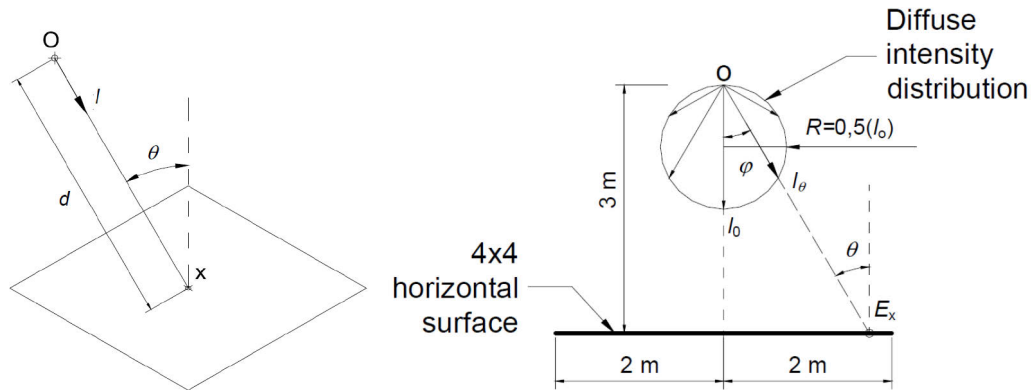
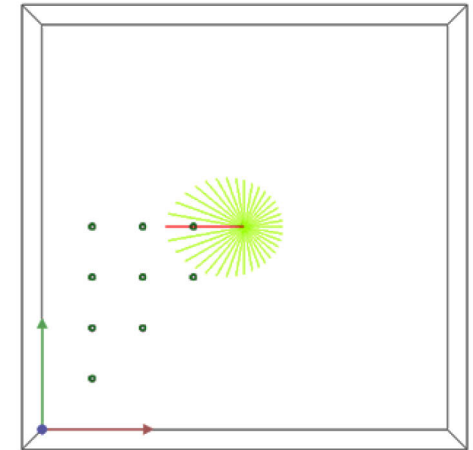


Figure 3: Direct illuminance calculation [CIE 171:2006]



5.3

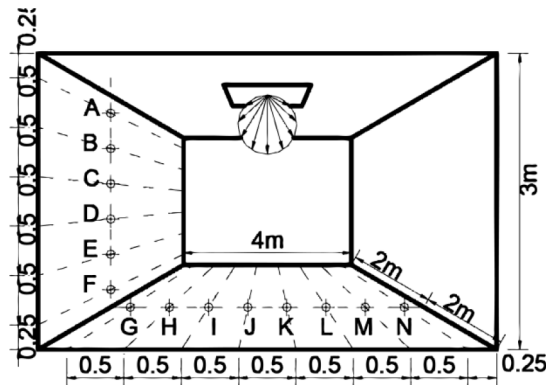
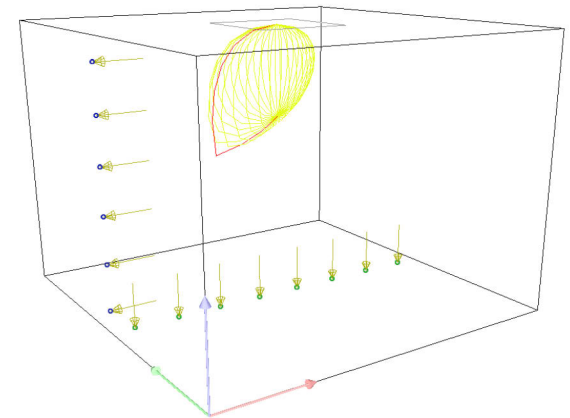
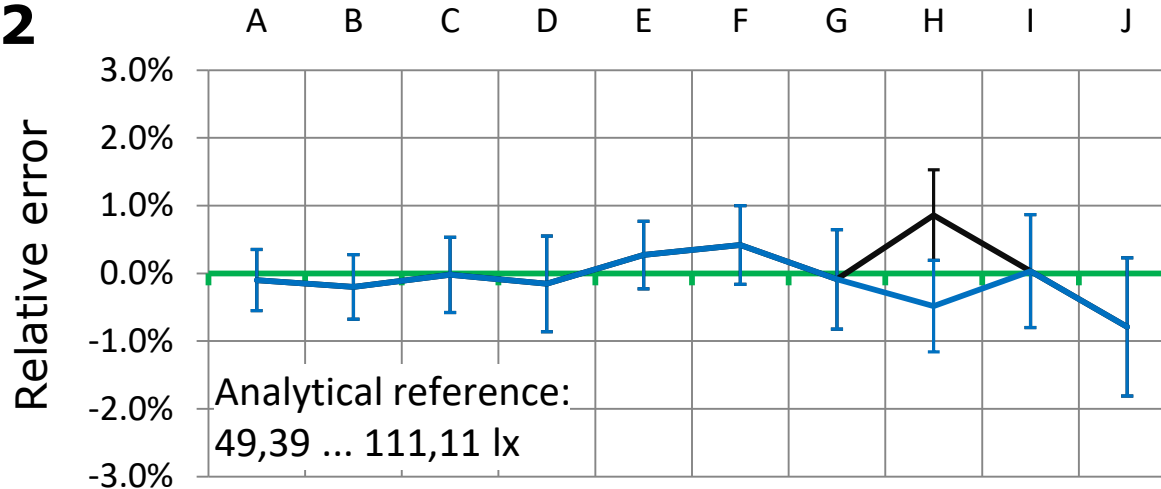


Figure 7: Geometry and measurement points description [CIE 171:2006]



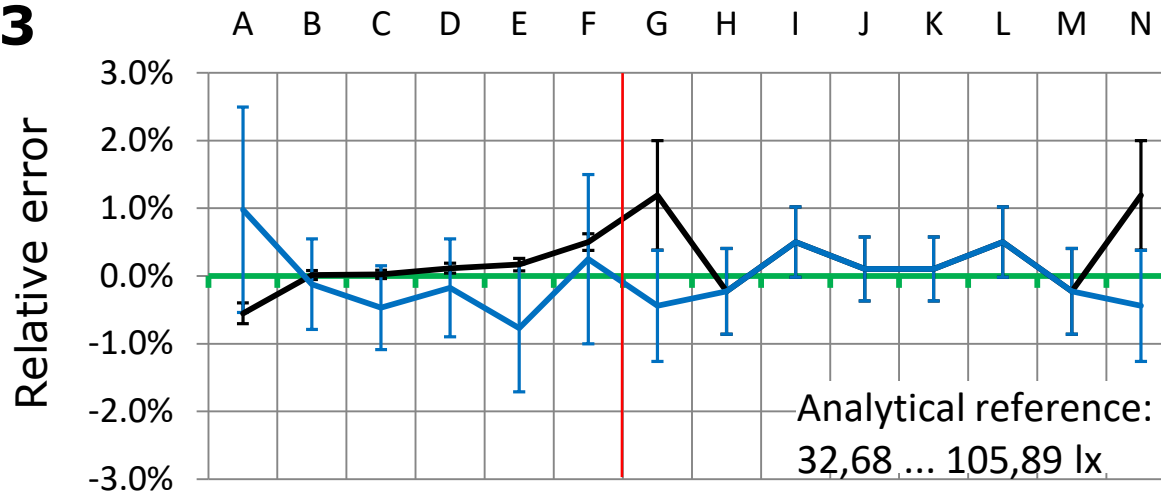
Analytical Test Cases 5.2/5.3

5.2



Point Light Source
Lambertian LID

5.3

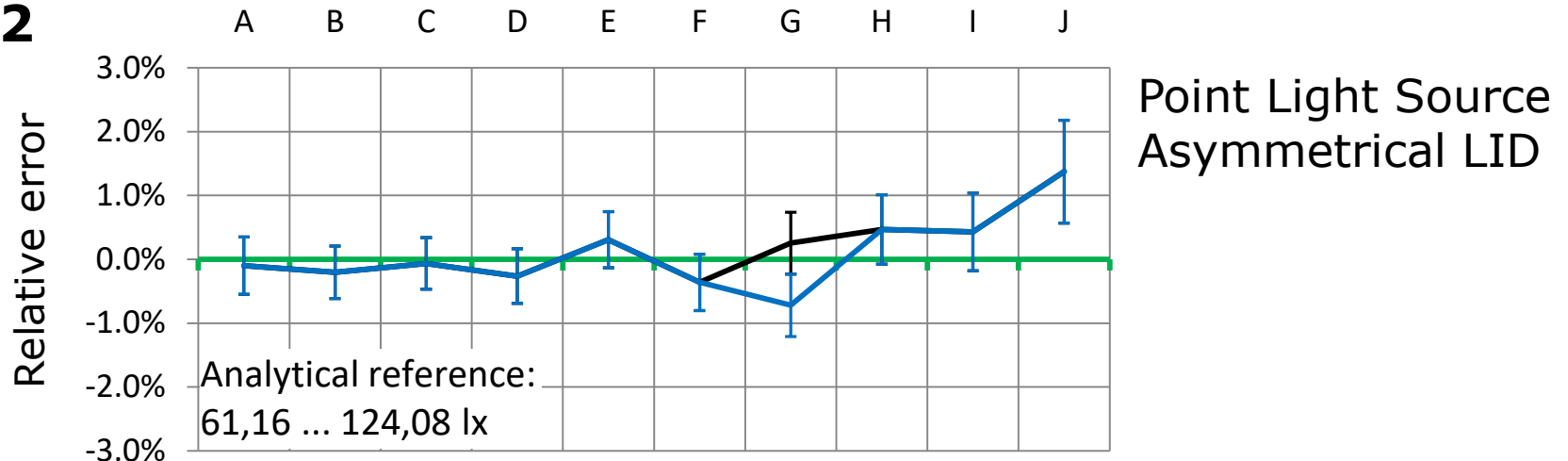


Area Light Source
Lambertian LID

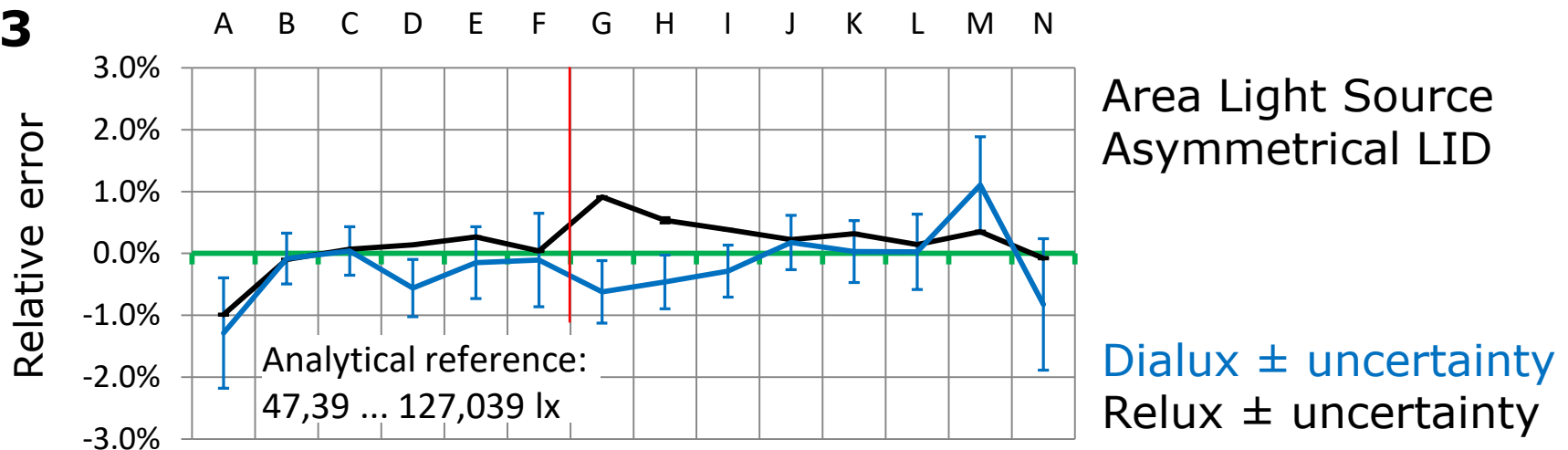
Dialux ± uncertainty
Relux ± uncertainty

Analytical Test Cases 5.2/5.3

5.2



5.3



Experimental Test Cases

- 4.1 CFL, grey
- 4.2 Opal, grey
- 4.3 Semi-specular, grey
- 4.4 CFL, black
- 4.5 Opal, black
- 4.6 Semi-specular, black

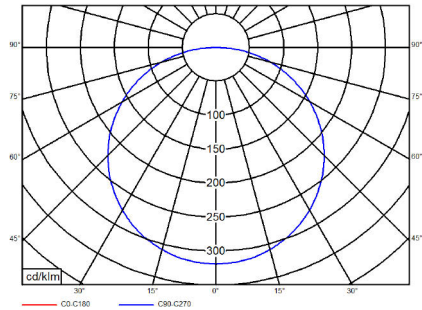
Analytical Test Cases

- 5.2 Point Light Sources
- 5.3 Area Light Sources
- 5.4 Flux Conservation
- 5.8 Internal reflected component calculation for diffuse surfaces

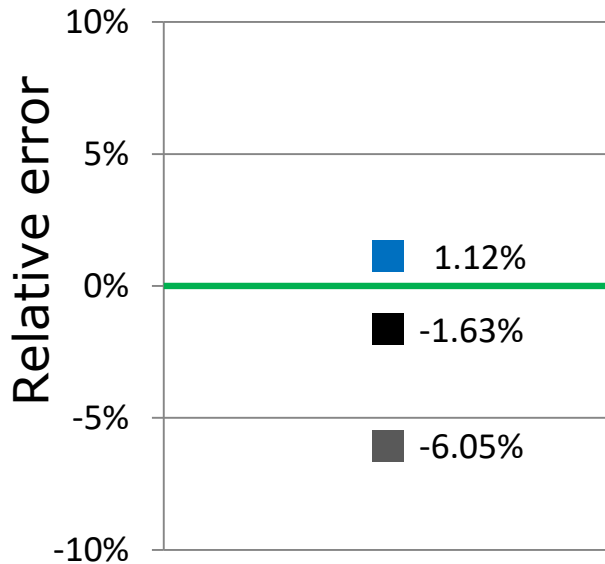
Analytical Test Case 5.4

Aim		To assess the luminous flux conservation between the light source and the internal surfaces of a space
Measured parameter		Average illuminance at room surfaces
Result		$R_s = \varphi_i / \varphi_o$ Error (%) = $100 \cdot (R_s - 1)$
Setting	Room geometry	4,0 m x 4,0 m x 4,0 m
	Reflectance	Ceiling, Wall, Floor $\rho = 0 \%$
	Luminaire position	2,0 m; 2,0 m; 4,0 m
	Luminous flux input	2500 lm
Varied parameter	LID	Lambertian LID Middle beam LID
	Measurement grid	/Relux (grid spacing: 0,53; 0,1)
	Calculation mode	Dialux
		(mode: standard; very accurate)

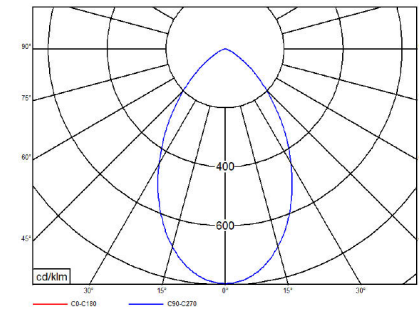
Analytical Test Case 5.4



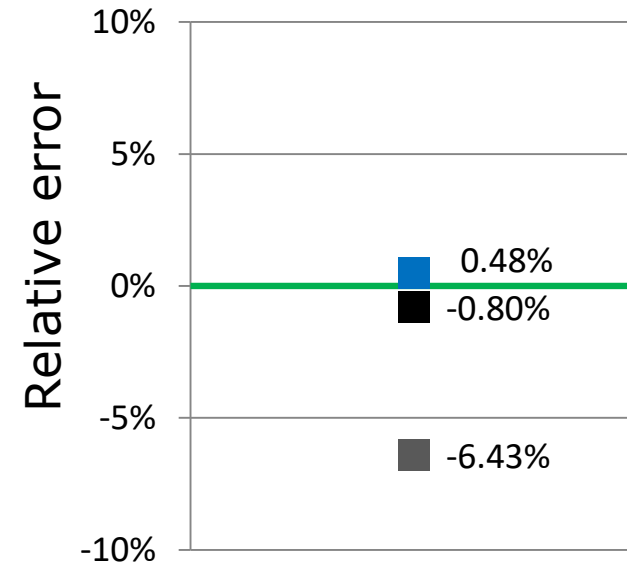
Lambertian LID



Dialux (all modes)
Relux (grid 0,1)
Relux (grid 0,53)



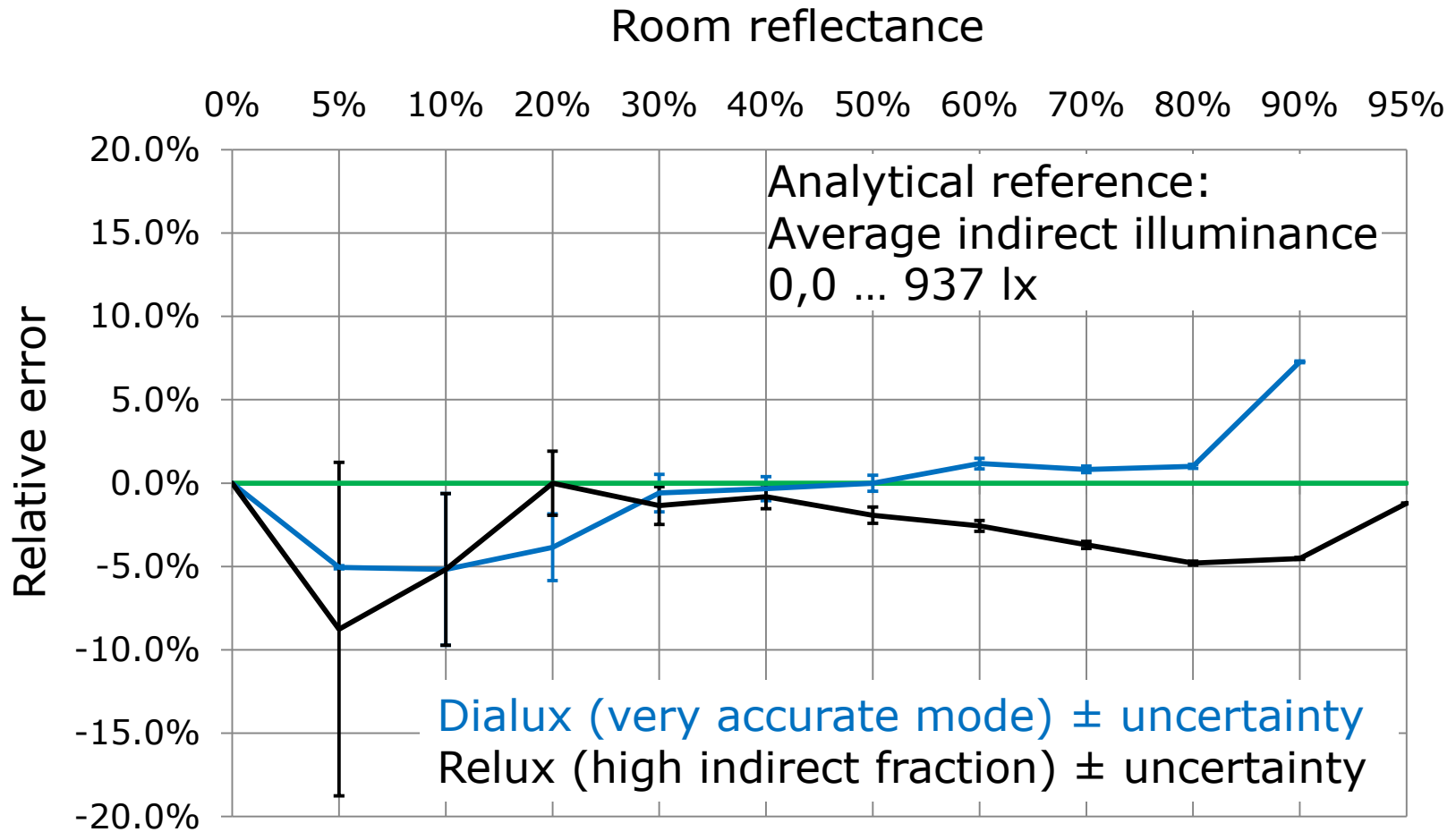
Middle Beam LID



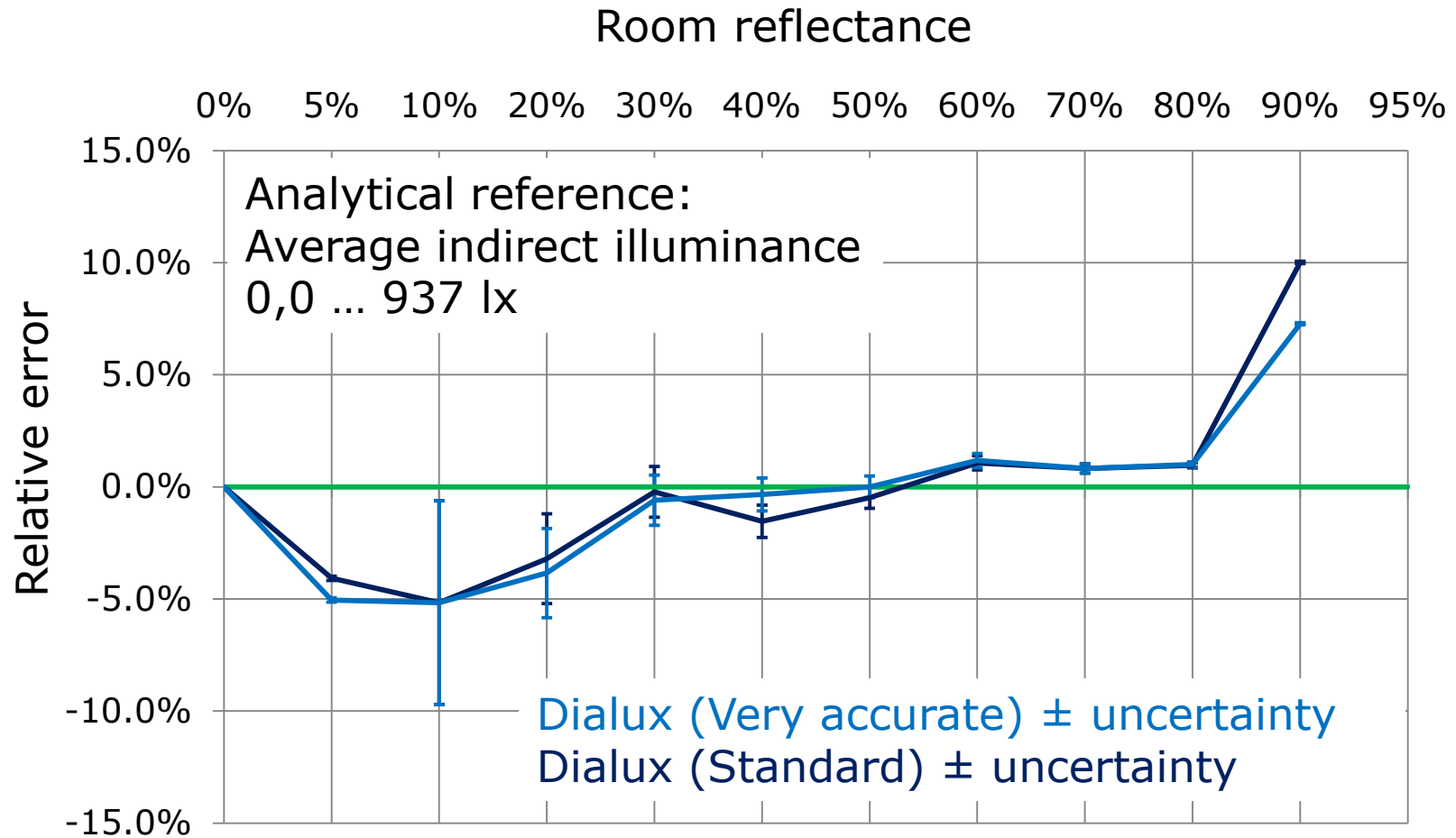
Analytical Test Case 5.8

Aim		To assess the accuracy of the diffuse inter-reflections inside a room
Measured parameter		Average indirect illuminance at room surfaces
Result		$\text{error (\%)} = 100 * (\bar{E}_{\text{ind, Simulation}} / \bar{E}_{\text{ind, Analytical}} - 1)$
Setting	Room geometry	4,0 m x 4,0 m x 4,0 m
	LID	Isotropic LID
	Luminaire position	2,0 m; 2,0 m; 2,0 m
	Luminous flux input	10.000 lm
Varied parameter	Reflectance	Ceiling, Wall, Floor $\rho = 0; 5; 10; 20; 30; 40; 50; 60; 70; 80; 90; (95) \%$
	Calculation mode	Relux (Low , average & high indirect fraction) Dialux (Standard; very accurate)

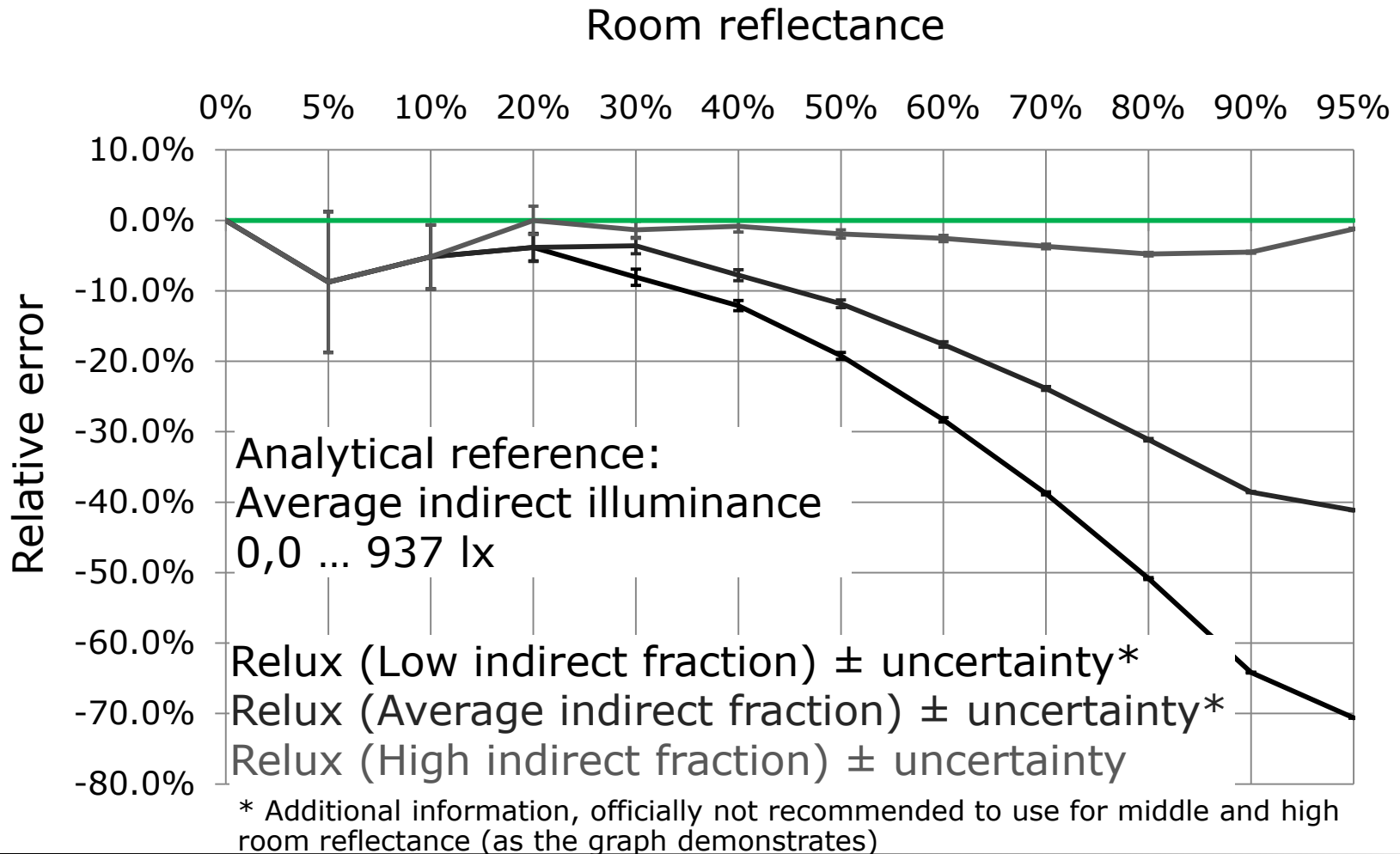
Analytical Test Case 5.8



Analytical Test Case 5.8



Analytical Test Case 5.8



Experimentell

Einzelne Abweichungen bei
Punktbeleuchtungsstärken ($\pm 2 \times 6,7\%$)
(Graue Wände, Opale Leuchten)

Keine Abweichungen bei mittlerer
Beleuchtungsstärke ($\pm 2 \times 6,3\%$)

Keine Unterschiede zwischen Dialux
und Relux

→ Für Situationen mit "gleichmäßiger"
LVK zur Berechnung horizontaler
Beleuchtungsstärken (direkt;
direkt/indirekt bis $\rho = 70/52/6\%$)
innerhalb der Toleranz unkritisch

Analytisch

Keine Abweichungen für Punkt- und
Flächenlichtquellen ($\pm 3\%$) für direkte
Beleuchtung (sym., asym.)

Keine Abweichungen für
Lichtstromerhalt ($\pm 2\%$) für direkte
Beleuchtung (Lamberstrahler, engstr.)
! Relux: feines Raster

Einzelne Abweichungen für
Indirektanteil ($\pm 10\%$)
! Rundung bei niedrigen ρ
! Dialux/Relux sehr genaue
Berechnung

Unterschiedliche Einstellmöglichkeiten
für genaue Berechnung

→ kein einheitliches Urteil

CIE 171:2006: Test Cases to assess the Accuracy of Lighting Computer Programs, ISBN 9783901906473

Fontoynt M., Laforgue, P., Mitanchey, R., Aizlewood, M., Butt, J., Carroll, W., Hitchcock, R., Erhorn, H., De Boer, J., DirksMöller, M., Michel, L., Paule, B., Scartezzini, J-L., Bodart, M and Roy G., 1999. Validation of daylighting computer programs. IEA SHC Task 21/ECBCS Annex 29.

Geisler-Moroder, Dür: Validation of Radiance against CIE 171:2006 and Improved Adaptive Subdivision of Circular Light Sources, 2008

Maamari, F., Fontoynt, M: Analytical tests for investigating the accuracy of lighting programs, Lighting Research and Technology 2003 35: 225

Ochoa, Aries, Hensen: State of the Art in Lighting Simulation for Building Science: A Literature Review, 2011

Vielen Dank!



Diese Studie wurde von Carolin Liedtke (Technische Universität Berlin, FG Lichttechnik) erstellt im Rahmen der Arbeit des Expertenforums Innenbeleuchtung (EFI) der LiTG e.V.

Die Daten wurden erhoben mit der Unterstützung von Dipl.-Ing. Nils Haferkemper, Photometrik GmbH und Maria Papamichali (ehem. FG Lichttechnik, TU Berlin), Athen